

Near Real-time Remote Sensing Data and Earth Science Priorities

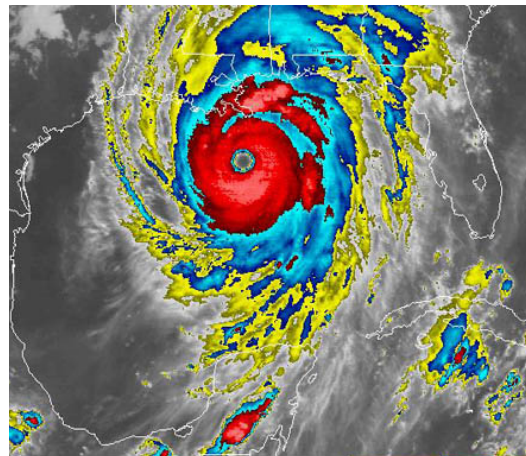
A Conceptual Perspective Focused on
Satellite Based Systems

Christopher D. Lippitt, PhD, CMS-RS
Department of Geography and Environmental Studies
University of New Mexico

The Potential of NRT Remote Sensing

Access to information from remote sensing sources in 'reactionable' timescales has broad implications for earth science, hazard response, and security:

- Continuous passive monitoring for unanticipated anomalies
- Automated target prioritization
- New/improved application domains
 - e.g., hazard response
 - e.g., tactical observation of transient phenomena
 - e.g., informed, coordinated field campaigns



TSRS: Natural Hazard Response

A far from complete list.....

- Fire (Galindo *et al.* 2003; Laneve *et al.* 2006; Visser and Dawood 2004)
- Earthquakes (Cervone *et al.* 2006)
- Volcanoes (Davies *et al.* 2006)
- Landslides (Joyce *et al.*, 2008)
- Flooding (Ip *et al.*, 2006)

Operational Programs:

- USGS Hazards Data Distribution System (HDDS)
- University of Hawaii near-real-time monitoring of thermal hotspots (MODIS and GOES)
- Geoscience Australia near-real-time monitoring of thermal hotspots (MODIS and AVHRR)
- University of Maryland Fire Information System
- Sentinel Asia
- The International Charter 'Space and Major Disasters'

TSRS: Other Examples

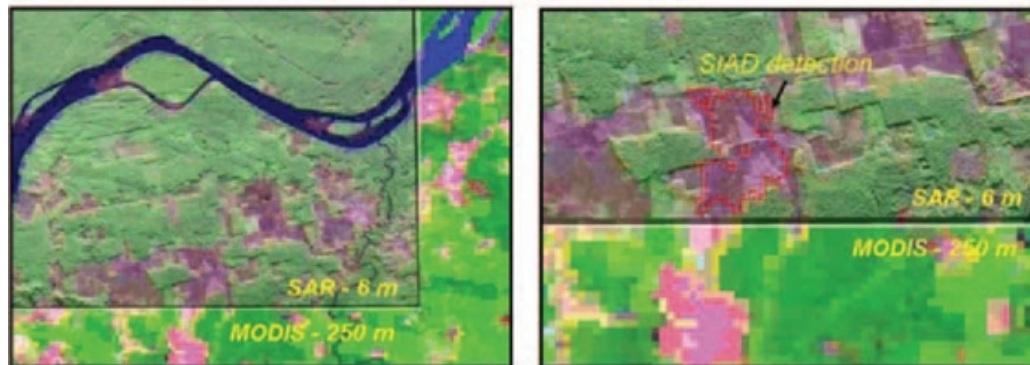
A far from complete list.....

Anthropogenic hazards

- Oil slick detection (Brekke and Solberg 2005)
- Air Pollutants (Simonds et al. 1994)

Resource Management

- Precision agriculture (Seelan et al. 2003)
- Wildlife management and food security (Sannier et al. 1998)
- Deforestation monitoring (Ferreira et al. 2007)



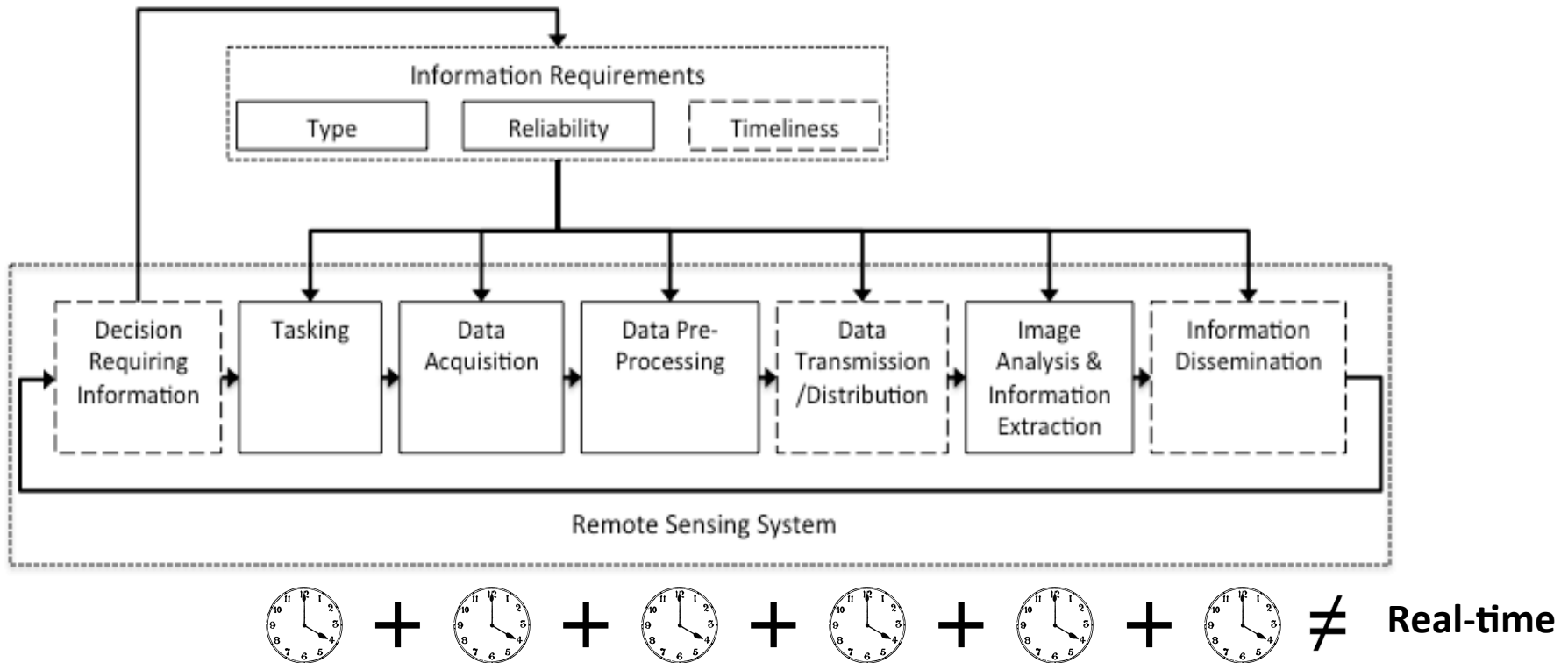
The use of Remote Sensing to Inform Time-Sensitive Decisions

“there is a critical need for real-time data and information....There was certainly ample evidence from the 11th September 2001 events that time dependence, scale, and even organizational issues (including interoperability, connectivity, and agency cooperation) thwarted the use of remote sensing imagery” (p. 443, Cutter 2003)

The effective use of GIScience technologies for hazard response requires that all data sources, processing flows, and distribution mechanisms be determined before the event they are intended to monitor

Not just a technical problem!

Time-Sensitive Remote Sensing



“Given that airborne and satellite sensor systems are inherently remote and that the data they collect are rarely employed in their raw form (i.e., voltages or exposed silver halide crystals) or near their origin (i.e. the sensor), time is inherent in the remote sensing process.” (Lippitt, Stow, and Clarke 2014)

What is Time-Sensitive Remote Sensing?



A Decision

Turn back? Or keep going?



Consequence

Splat

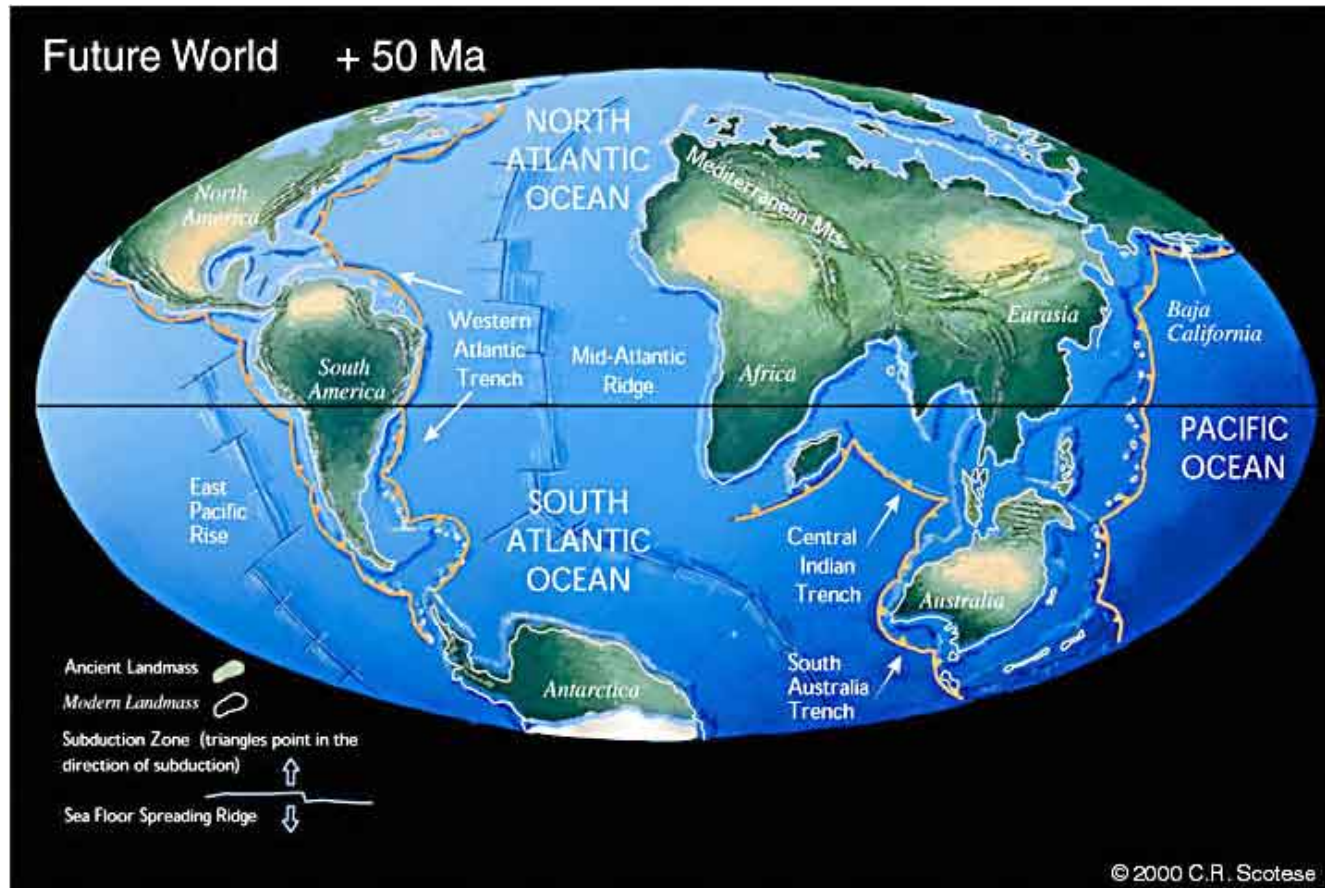


Information Required

What direction is the next car coming from?

“the use of remote sensing systems and methods to gather information where the utility of that information to inform a given decision changes as a function of time.” (Lippitt, Stow, and Clarke 2014)

What is Time-Sensitive Remote Sensing?



A Decision

Where to evacuate?

Consequence

Destruction of civilizations dating to the start of human history

Information Required

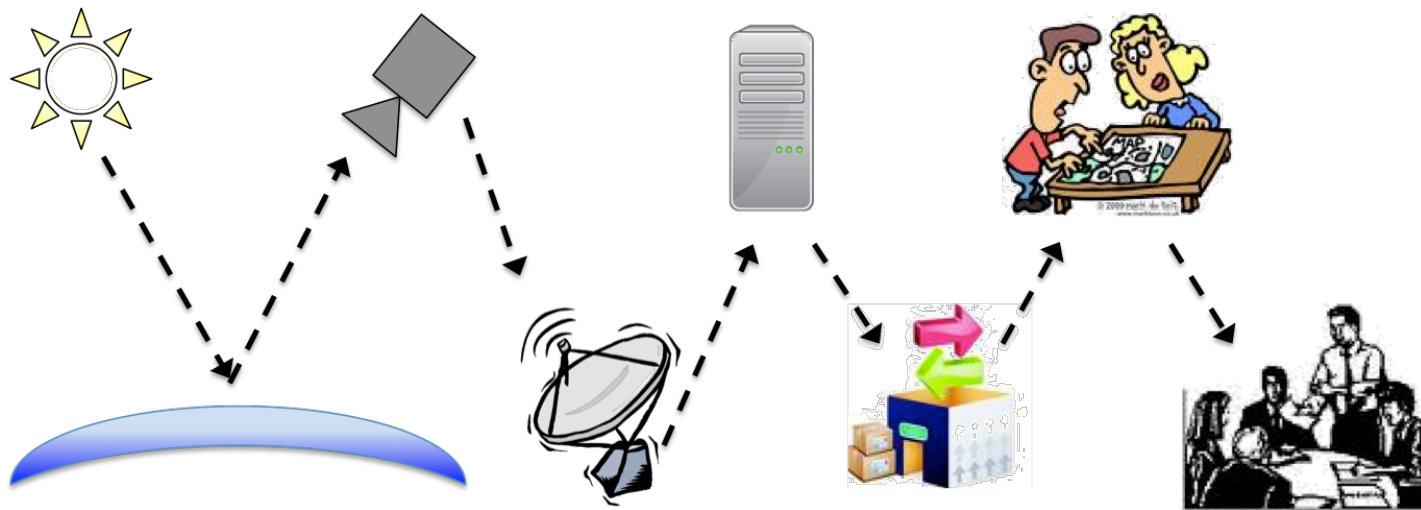
What land areas will still be inhabitable

50 million years

*“From a practical perspective however, it is only when information from a remote sensing source is required within timescales that **approach the limits of current technology and practice** that timeliness becomes a dominant control on the effectiveness of the decisions in which that information is employed. Therefore, we consider only these cases to be TSRS.” (Lippitt, Stow, and Clarke 2014)*

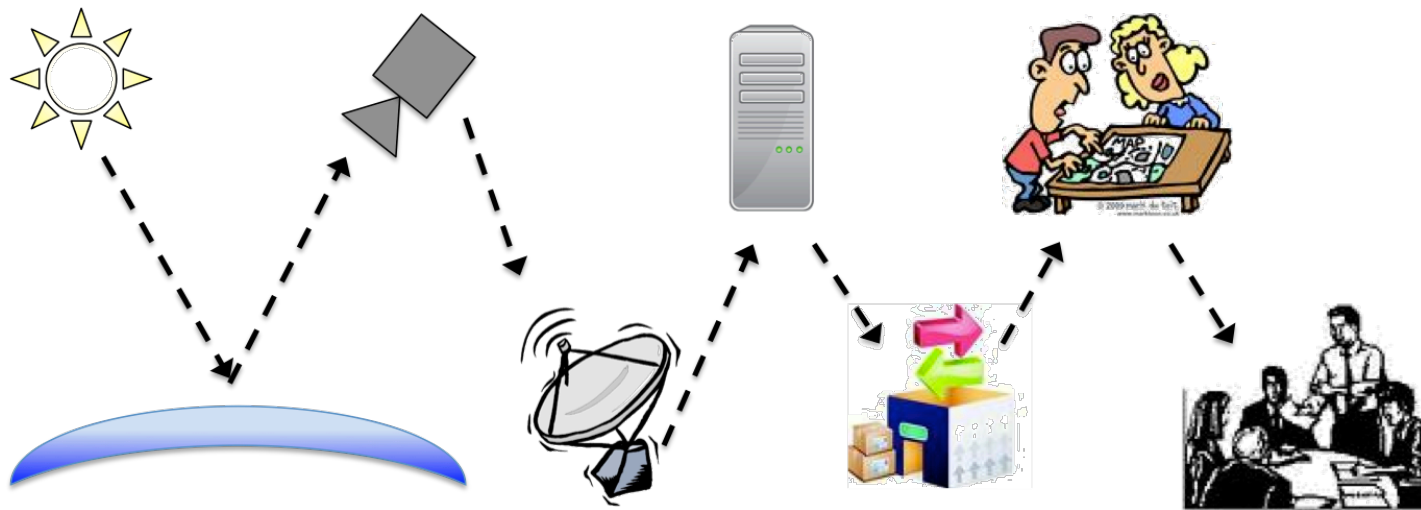
Remote Sensing System Definition

All systems and methods required to measure electromagnetic energy intensity, interpret it into information, and deliver it to a user



Remote Sensing System *Component* Definition

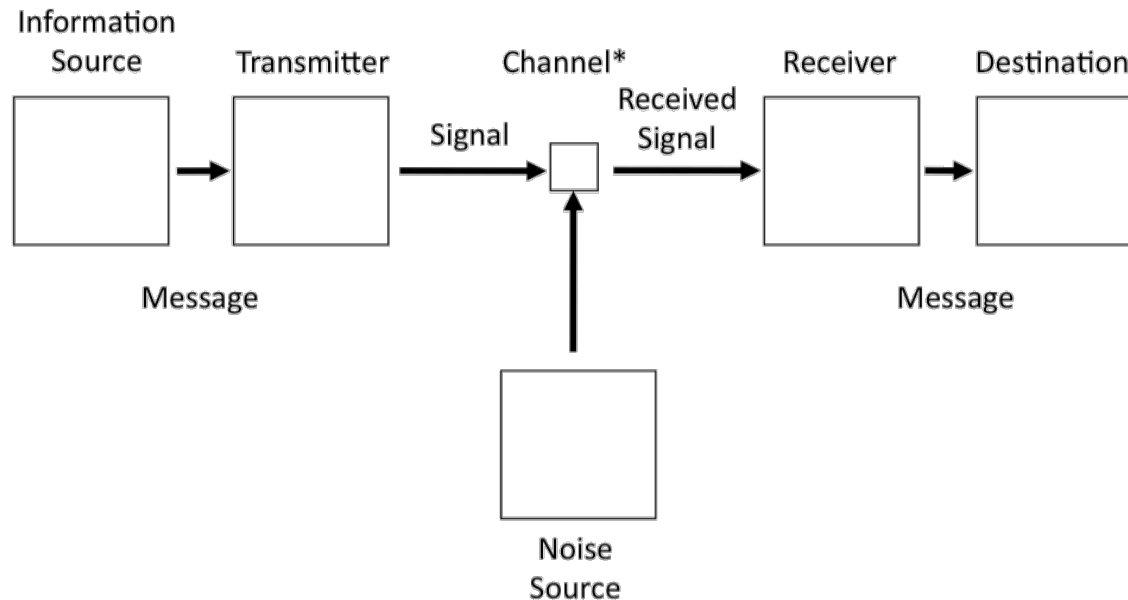
Pieces of equipment, people, or methods that compose a system to measure electromagnetic energy intensity, interpret it into relevant information, and deliver it to a user



A Mathematical Theory of Communication

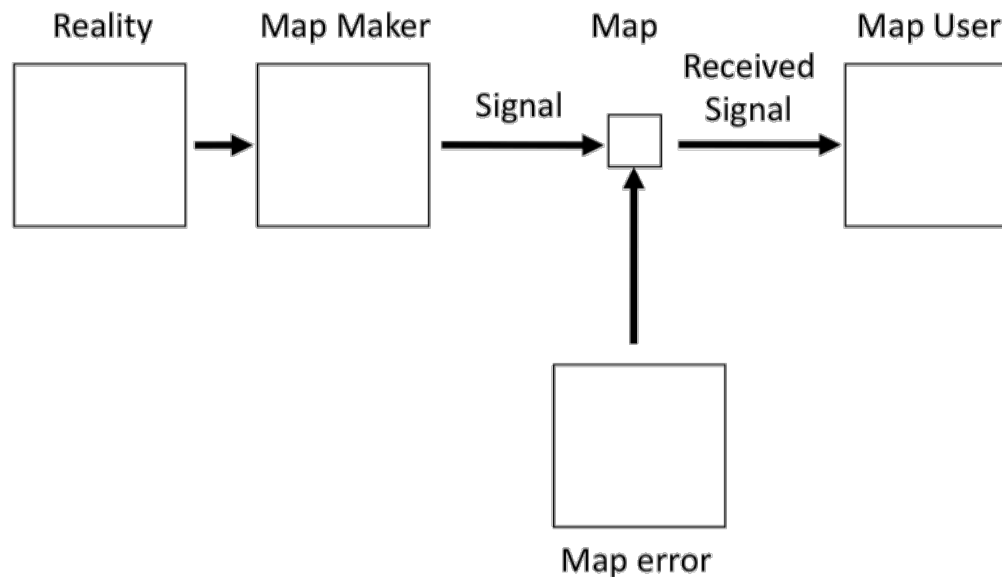
Proposed by Shannon (1948) and elaborated on by Shannon and Weaver (1963)

- Foundation of what is now known as ‘Information Theory’
- the problem of “reproducing at one point either exactly or approximately a message selected at another point”



The Map Communication Model

- Conceptualizes the map as a channel
- Emphasizes that what is encoded by the cartographer is different that what is perceived by the map-reader
- Demonstrates the use of communication models to explain the production and consumption of geographic information (Robinson and Petchenick 1976).



The Map Communication Model

“cartographic work cannot obtain its maximum effect if the cartographer looks upon the production and the consumption of the map as two independent processes. That maximum effect can only be obtained if he considers the creation and utilization of works of cartography to be two components of a coherent and in a sense indivisible process in which cartographical information originates, is communicated, and produces an effect...” (Kolacny 1968)

Communication

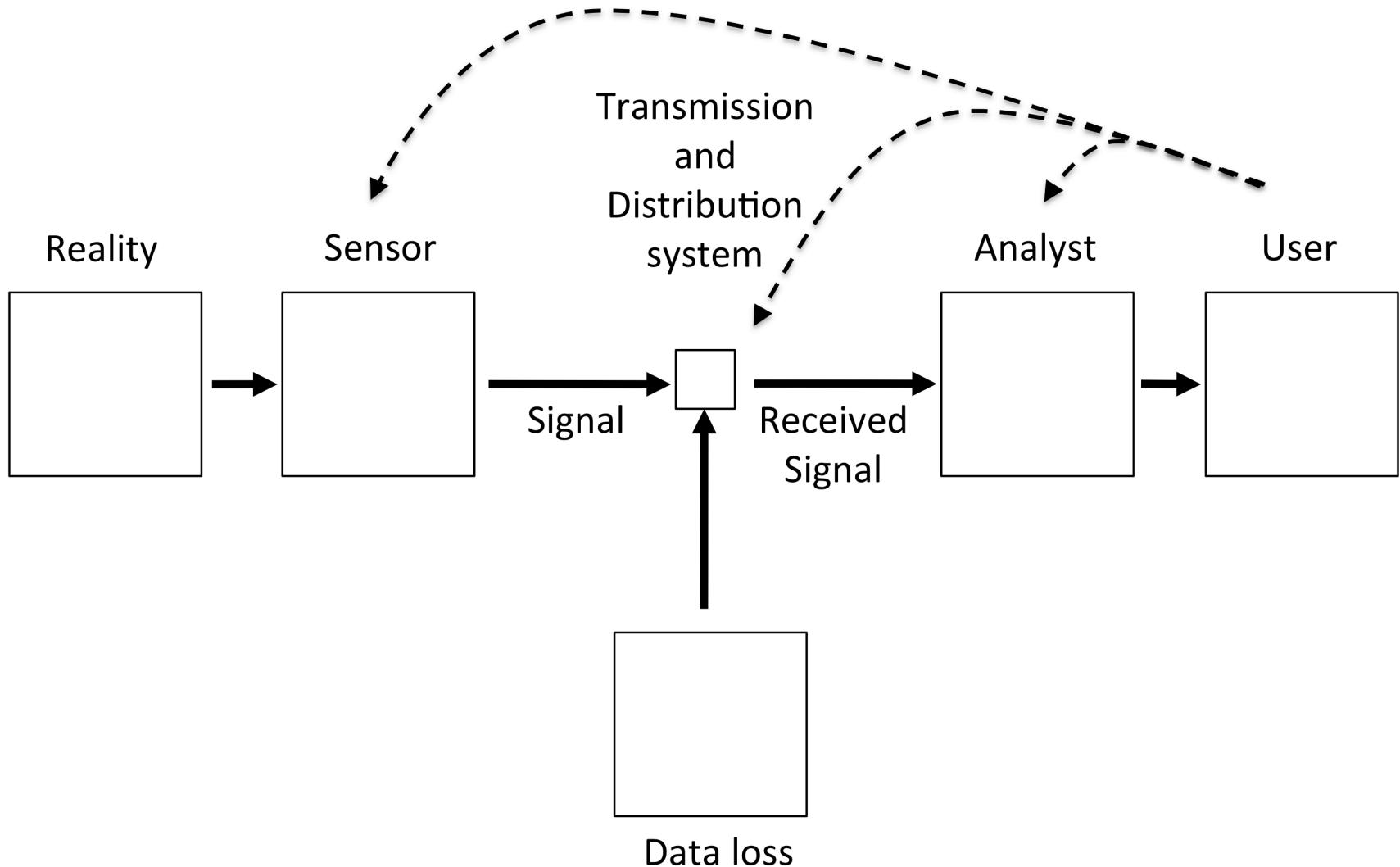
Shannon and Weaver (1963) argue that information value is affected by three levels of communication:

Level A the accurate transmission of symbols (i.e., the Technical problem),

Level B the proper interpretation of those symbols into a given meaning (i.e., the Semantic problem) and

Level C the effect of the receipt of those interpreted symbols (i.e., the Effectiveness problem)

The Remote Sensing Communication Model



The Remote Sensing Communication Model

According to Shannon and Weaver

the accurate transmission of symbols (i.e., Technical problem),



the proper interpretation of those symbols into a given meaning (i.e., Semantic problem)



the effect of the receipt of those interpreted symbols (i.e., Effectiveness problem)



A Remote Sensing System

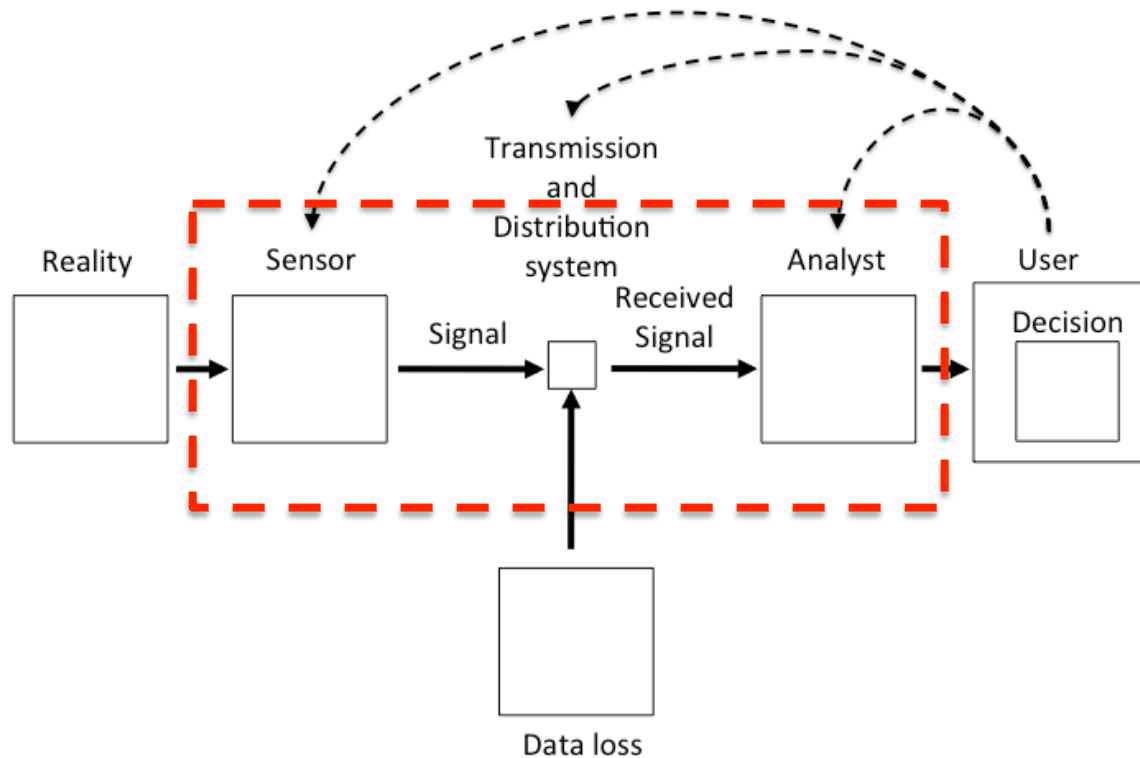
data delivered to an analyst must accurately characterize the phenomena of interest

analyst must properly interpret those data into information that is relevant to the user

the information must produce an effect when delivered to the user

The Remote Sensing Communication Model

Transmitters (Sensors), Channels (Transmission and Distribution Systems), and Receivers (Analysts) all have a capacity in Volume/Unit time



The Goal

To maximizing the effectiveness of the information produce by Remote Sensing System(s?)

- Minimize time-to-information (Maximize the capacity) of Remote Sensing System(s?)
- Maximize product utility

Sensor (Transmitter) Capacity

Sensor Capacity

A product of platform and sensor characteristics

$$C_S = \beta B_A$$

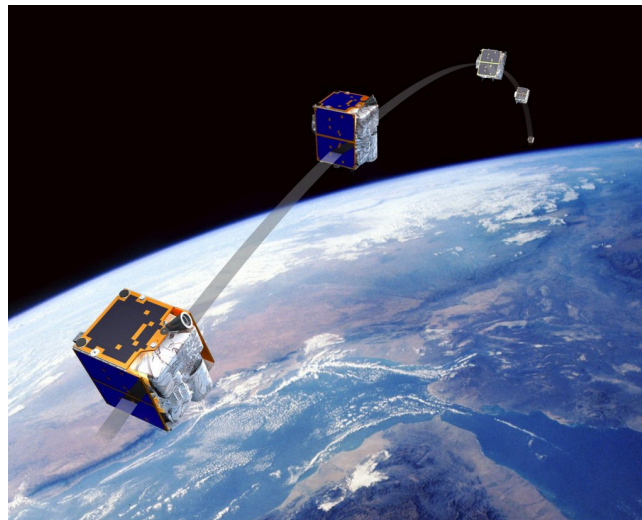
C_S = sensor capacity in bits
per unit time
 β = rate of acquisition in area
per unit time assuming no
end lap or side lap
 B_A = bits per unit ground
area

$$T_A = \frac{B_S}{C_S} + T_D + T_M(N - 1)$$

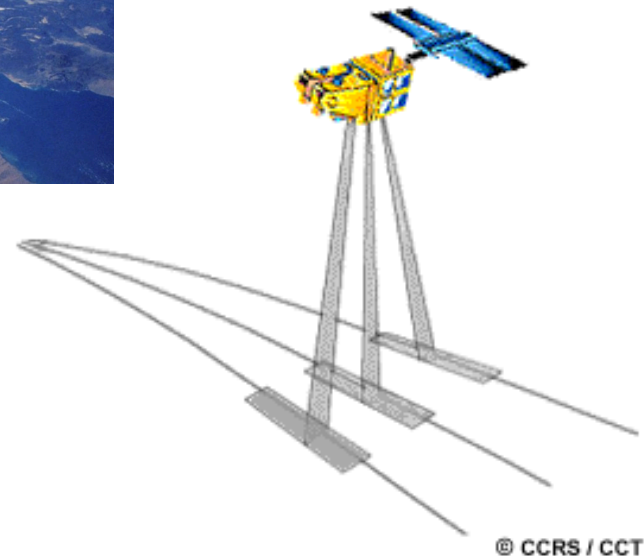
T_A = total acquisition time
 T_D = time required to deploy to the scene
 T_M = time required to maneuver the
platform between flight lines or paths
 N = number of flight lines or paths
required to image the scene
 B_S = total number of bits required to image
a given scene

Sensor (Transmitter) Capacity

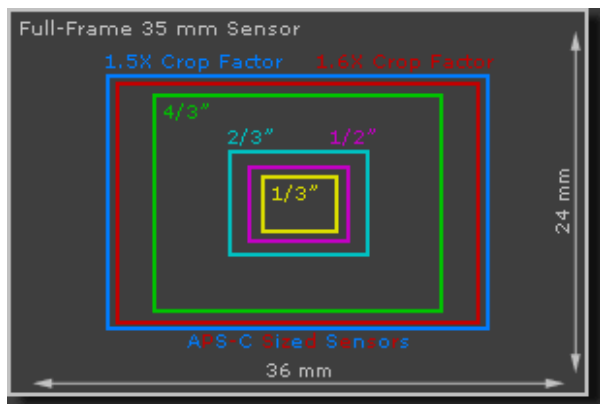
Options to minimize time:
Constellations



Point able Sensors



Larger Detectors



Channel Capacity

Channel Capacity

A product of communication mechanisms

$$T_C = \sum_{i=1}^n \frac{B_S}{C_{C,i}} + L_i$$

T_C = time required to transmit data from the sensor to the analyst

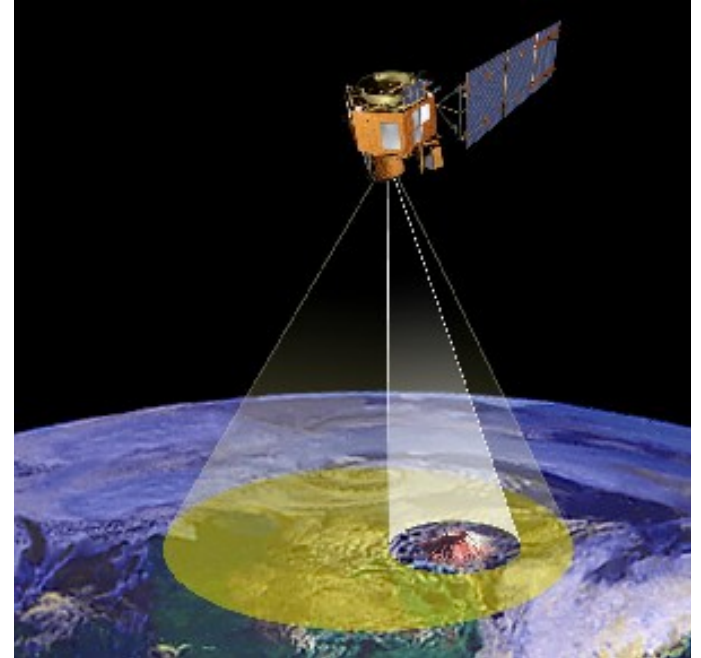
$C_{C,i}$ = channel capacity in bits per unit time for channel segment i ,

L_i = latency in the system for channel segment i in units of time

Channel Capacity

Options to minimize time;

- Reduction of resolution (Spectral, Spatial, Radiometric)
- Shorter transmission path
- Higher bandwidth
- Onboard processing



ase.jpl.nasa.gov

Analyst (Receiver) Capacity

Receiver Capacity: Automated

A product of the desired information relative to the data received

$$C_{Aa} = \frac{h}{\phi}$$

$$\phi = \frac{\sum_{i=1}^n a_i}{P_S}$$

$$T_R = \frac{P_S + P_R}{C_{Aa}}$$

$$a_i \in \{\log P_S, \dots, P_S, \dots, P_S \log P_S, \dots, P_S^2, \dots, P_S!\}$$

C_{Aa} = receiver capacity in
records per unit time

P_S = total number of samples
required to image a scene

P_R = number of records
of ancillary data

h = rate of processing in hertz
(sec^{-1})

ϕ = computational cycles per
record required to extract the
required information

Analyst (Receiver) Capacity

Receiver Capacity: Human

A product of the desired information relative to the data received

$$T_R = \left(\frac{O_A}{A_S} \right) \frac{1}{C_{Ah}}$$

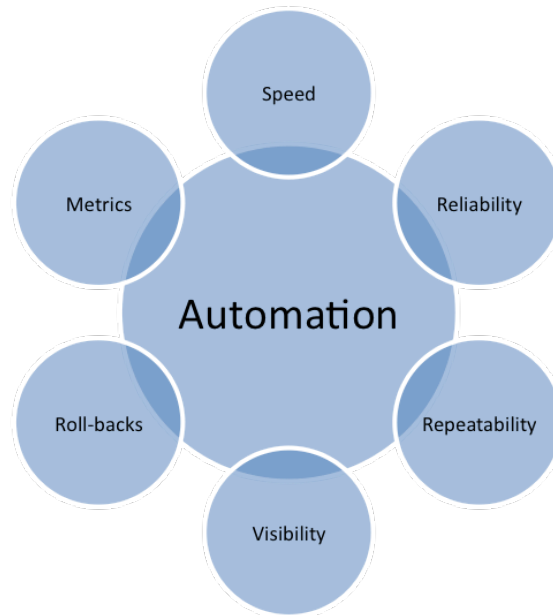
O_A = the minimum mapping unit

C_{ah} = the efficiency of an analyst at interpreting the phenomena of interest from the image of interest in units of the number of O_A per unit time

Analyst (Receiver) Capacity

Options to minimize time

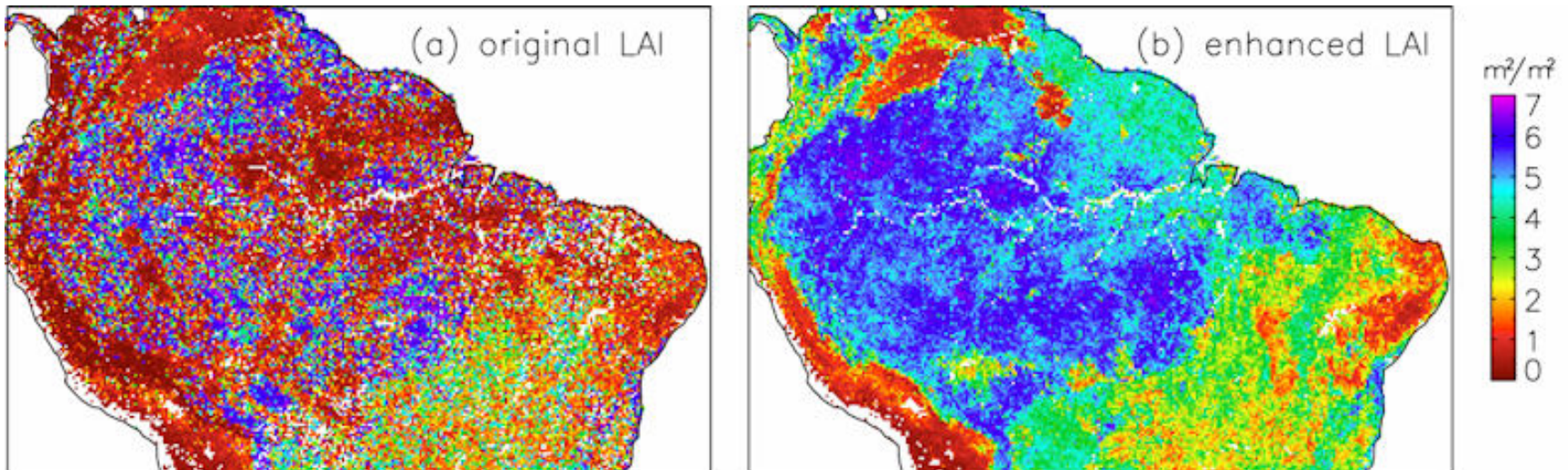
- More resources (Hardware/Human)
- More customized resources (e.g., FPGA, GPU)
- Automated workflows



Level A: The Technical Problem

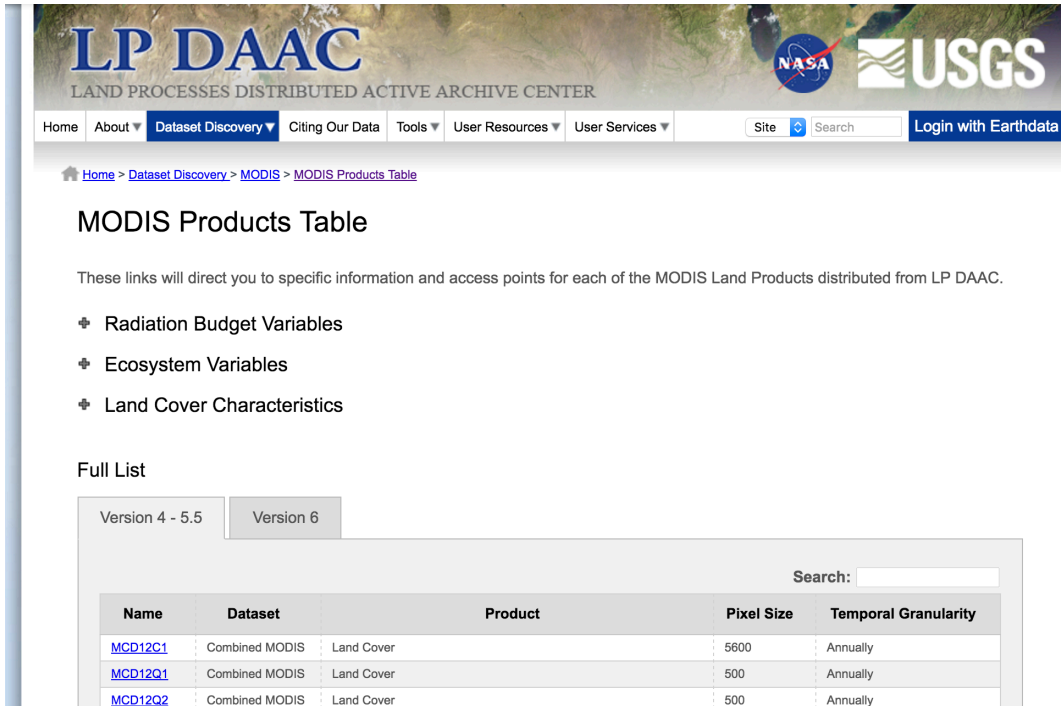
“Data delivered to an analyst must accurately characterize the phenomena of interest”

The traditional strength of Remote Sensing



Level B: The Semantic Problem

“analyst must properly interpret those data into information that is relevant to the user”



The screenshot shows the LP DAAC (Land Processes Distributed Active Archive Center) website. The header includes the LP DAAC logo, NASA and USGS logos, and a navigation menu with links like Home, About, Dataset Discovery, Citing Our Data, Tools, User Resources, and User Services. Below the header, the breadcrumb trail reads: Home > Dataset Discovery > MODIS > MODIS Products Table. The main heading is "MODIS Products Table". A subtext explains: "These links will direct you to specific information and access points for each of the MODIS Land Products distributed from LP DAAC." Below this, there are three expandable sections: "Radiation Budget Variables", "Ecosystem Variables", and "Land Cover Characteristics". The "Full List" section is active, showing two tabs: "Version 4 - 5.5" and "Version 6". A search bar is present above a table. The table has five columns: Name, Dataset, Product, Pixel Size, and Temporal Granularity. It lists three products: MCD12C1, MCD12Q1, and MCD12Q2, all from the "Combined MODIS" dataset, with "Land Cover" as the product, "5600" or "500" as pixel size, and "Annually" as temporal granularity.

LP DAAC
LAND PROCESSES DISTRIBUTED ACTIVE ARCHIVE CENTER

Home About Dataset Discovery Citing Our Data Tools User Resources User Services Site Search Login with Earthdata

Home > Dataset Discovery > MODIS > MODIS Products Table

MODIS Products Table

These links will direct you to specific information and access points for each of the MODIS Land Products distributed from LP DAAC.

- ✚ Radiation Budget Variables
- ✚ Ecosystem Variables
- ✚ Land Cover Characteristics

Full List

Version 4 - 5.5 Version 6

Search:

Name	Dataset	Product	Pixel Size	Temporal Granularity
MCD12C1	Combined MODIS	Land Cover	5600	Annually
MCD12Q1	Combined MODIS	Land Cover	500	Annually
MCD12Q2	Combined MODIS	Land Cover	500	Annually

Products targeted to specific user groups (e.g., hazard managers) help better satisfy the semantic problem

Level C: The Effectiveness Problem

“information must produce an effect when delivered to the user”

- Requires integrating into SOPs
 - reliable standardized products
- Outreach/training
- Making Remote Sensing more ‘accessible’
 - Reducing costs required (hardware, software, bandwidth)
 - Reducing training requirements
 - Engineering products for ease of use

I believe this is our ‘last mile’ and principle challenge

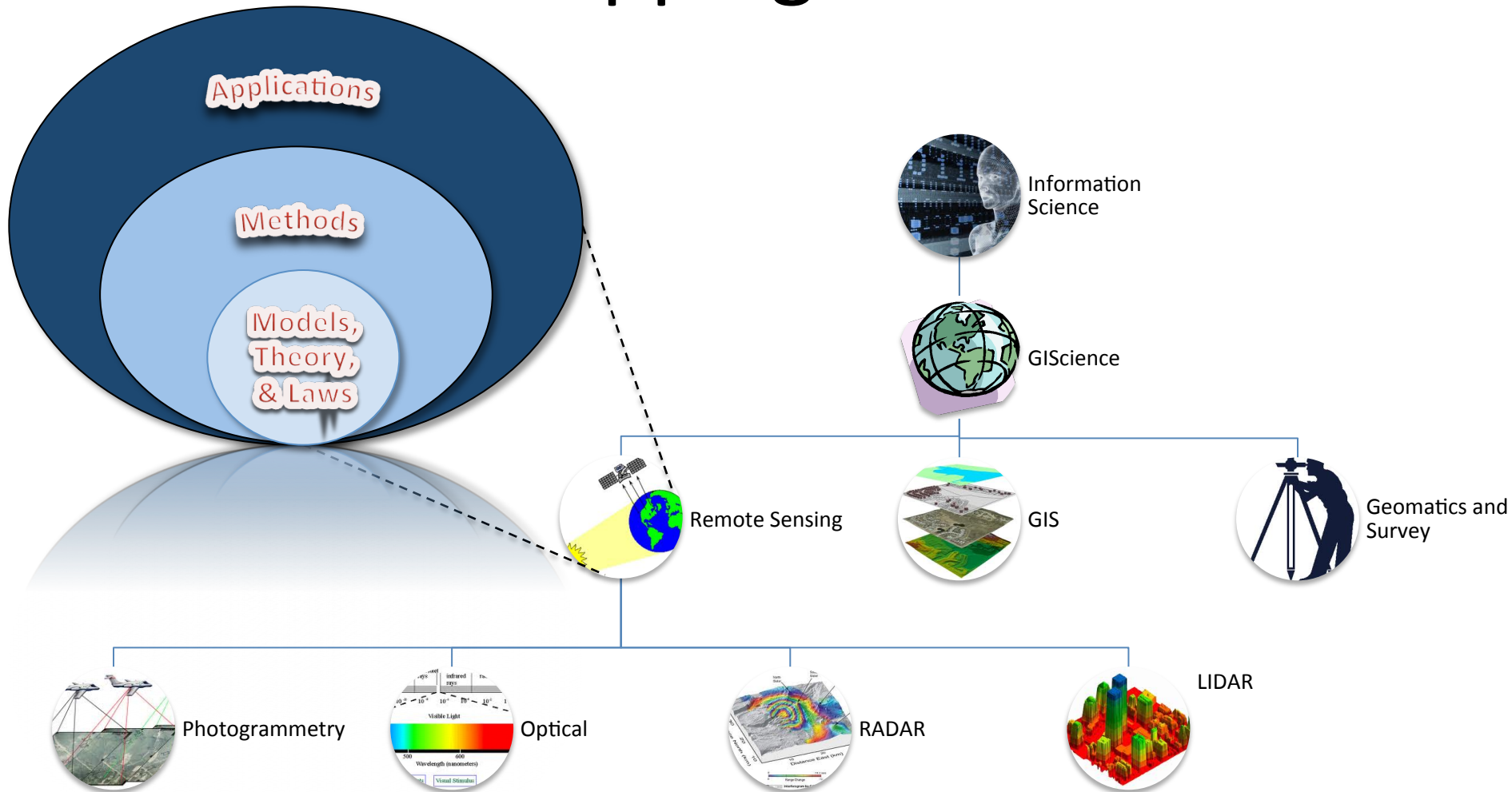
So What?: Recommendations for Increasing the Effectiveness of Current and Future Remote Sensing Systems

- Continue to 'MODISize'
 - Automated products customized to specific user groups
 - Offer API that allows users to automate custom products
- Move toward constellations of lower cost sensors
- Move preprocessing onboard
- Continue to automate processing routines

Recommendations for Increasing the Effectiveness of Current and Future Remote Sensing Systems

- Work toward high level, easy to use products
- Establish programs to integrate remote sensing into SOPs
- Produce 'flat' low volume products
- Establish central, high level Web 2.0 architecture for accessing and manipulating products

Stepping Back



Theory and models required to inform the engineering exercise

Thank You

For more information, contact:

Dr. Chris Lippitt

clippitt@unm.edu

Also see: Lippitt, C.D. 2015. Remote Sensing from Small Unmanned Platforms; a paradigm shift. *Environmental Practice* 17 (3): 235-6.

Lippitt, C.D., D.A. Stow, and K. Clarke. On the Nature of Models for Time-Sensitive Remote Sensing. *International Journal of Remote Sensing* 35 (18): 6815-41.

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